Regenerative Agriculture

We know more about the surface of the moon than the surface of the earth. The moon is composed of known mineral fragments, whereas soil is an ecosystem comprising trillions of living organisms, most of which remain unidentified. Biological systems created the earthen mantle hundreds of millions of years ago, and soils have been evolving ever since. When you gather a teaspoon of healthy soil, you are holding several billion organisms. You also have at hand one of the most complex living systems in the world, one that has been degraded and corrupted by industrial agriculture.

Regenerative agriculture has become the archetype and template for regeneration in general. That makes sense because it transforms farming from an extractive industry to one that restores soil health, the water cycle, biodiversity, human nutrition, animal health, pollinator and insect viability while preventing water pollution from run-off, soil erosion, diseases brought about by pesticides, and metabolic dysfunction caused by glyphosate.

World over, tens of thousands of farmers and ranchers are employing regenerative agricultural methods in order to reverse the loss of soil health and bring agriculture and food back to life. Regenerative agriculture systems include agroforestry, agro-ecology, silvopasture, pasture cropping, and advanced rotational grazing. It incorporates specific methods including no-till, complex cover crops, prairie strips, perennial crops, animal integration and crop diversification. One of the outcomes is carbon sequestration, significant increases in the carbon content of soils.

The word *regenerative agriculture* was coined forty years ago; however, its origins are ancient and go back thousands of years. There are records of lands being continuously cropped for many thousands years in the Americas, Africa, and Asia. One of the oldest forms of regenerative agriculture was practiced by Mayan farmers using a forest garden system known as *milpa*. Vegetation was cleared and burned in rotation, a fire ecology that created some of the most densely forested areas in the tropics in 10 to 25 year cycles of cultivation and reforestation. Corn, beans, and squash were planted in soil that was fertilized by biochar from the charcoal and nitrogen from the beans. China, Japan and Korea practiced regenerative agriculture for over 4,000 years and the results speak for themselves in that they represent some of the oldest civilizations on earth along with India. Regenerative practices were well in hand in Western Africa where the use of charcoal and green waste created durable "dark earths" that contain three to four times the fertility than the thin, nutrient poor rainforest soils. Enslaved African women braided rice and other seeds into cornrows as a means to ensure human and cultural survival, and African knowledge of regenerative agricultural practices was both relied upon in southern, white plantations but expressed scientifically and practically by George Washington Carver who can be acknowledged as the progenitor of regenerative agriculture in America.

Today, there is an explosion of learning, sharing experimentation, and collaboration around regenerative theory and practices, in no small part due to the damage visited upon the land by industrial agriculture and the "green revolution", which focused on bigger farms, higher-yielding hybrid seeds (which don't reproduce themselves), and increased use of chemical fertilizers and pesticides. Given today's science, and the growing interest by economically stressed conventional farmers, regenerative agriculture can deservedly be called an emergent technology. It is more complex than a smartphone, involves more interactions than the Internet, and has more moving parts than any machine or device. However, they are biological "parts", which is to say they are not parts at all but living elements within a system. Though regenerative agriculture is exponentially more intricate than any shiny object, it is based on clearly defined principles and is actionable by farmers and ranchers the world over. Importantly, its yields are commensurate or greater than conventional agriculture.

The excitement and emphasis on carbon sequestration as the primary purpose of regenerative agriculture obscures its overall impact as well as its historical origins. To be sure, if regenerative agricultural practices were phased in and implemented on one fourth of the world's farms and grasslands, they would absorb and retain a much needed 70 billion tons of carbon in the next thirty years. That aspect of regenerative agriculture has become appealing to industrial agriculture companies and large food manufacturers. From Anheuser-Busch to Bayer-Monsanto, from General Mills to Cargill, companies are adopting the term as their climate solution, which is causing confusion and dismay. Regenerative agriculture is a systems approach to soil, farming, and crops, not a menu that can be cherry-picked for good publicity. For Bayer-Monsanto to promote carbon sequestration is contradictory since they patented the largest selling pesticide in history, one that has been called the most destructive chemical in the world—glyphosate. Its best-selling herbicide was

The Chinese have been cultivating rice for at least 8,000 years. Over the past 1,300 years, the Hani people have developed a complex integrated farming system that involves buffalos, cattle, ducks, fish and eel and supports the sustainable production of red rice, the area's primary crop. The Honghe Hani rice terraces are an exceptional reflection of a resilient land management system that optimizes social and environmental resources, demonstrates harmony between people and their environment in spiritual, ecological and visual terms. Ducks fertilize the young rice plants, while chickens and pigs contribute fertilizer to more mature plants. Water buffalo cultivate the fields for the next year's planting and snails consume various pests. Yunnan's rice terraces are among the oldest human structures in China, farmed, as they always have been, by domesticated water buffalo, whose ancestors originated in these very valleys. The mountaintop forests are the lifeblood of the system, capturing the water that makes irrigation possible.

patented as an antibiotic, and it is. It kills the microbial life in the soil and the whole purpose of regenerative agriculture is to increase it.

A simple way to understand the difference between industrial and regenerative agriculture is by what is being fed. Industrial agriculture feeds the plants with chemical forms of nitrogen, phosphorus, and potassium. Regenerative agriculture feeds the soil, and the soil feeds the plant. Industrial agriculture takes a complex ecosystem of plants, soils, and insects and replaces it with monocultures, laser-guided tractors and sprayers, and combinations of chemicals inputs to obtain its outputs. Combinations of pesticides, herbicides, fertilizers, fungicides, and antibiotics have taken a toll on the soil, farmers, their families, and wildlife. The farm belt experiences higher rates of cancer and Parkinson's disease, and suicides among US farmers are among the highest of any profession in the world. As soil fertility declines, more inputs are required to maintain crop yields. As soils deteriorate, so too does plant health, making crops more susceptible to insects. As pesticides are used, natural predators vanish. At this point, a farmer is dependent on the thousands of different chemicals marketed to control plant and animal health. About one-sixth of global greenhouse gas emissions stem from agriculture.

Regenerative agriculture can reverse these conditions as it builds carbon in the soil. Scientists argue about how much carbon can be sequestered over the coming decades, a debate that does not mean much to a farmer. Farmers are converting in order to receive and store more water in their soil, lower their costs, stop erosion, increase their profits, and produce healthier plants, animals, and farm families. For many it is the way out of little or no profits and the unsupportable debt that has built up over many years. Below are descriptions of the basic principles, techniques, and outcomes of regenerative agricultural practices that restore soil, plant, and ecosystem health.

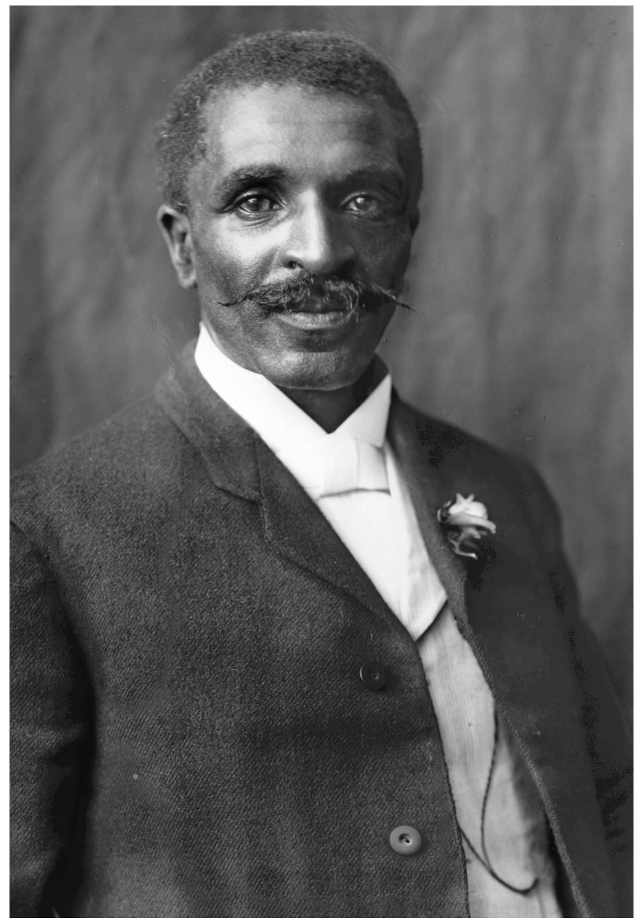
Carbonize the soil. The top six to seven inches of topsoil contain what is known as labile carbon, a type of carbon that cycles in and out with the seasons. Occluded carbon lies below in the subsoil and it does not escape so readily into the atmosphere. Root sugars called exudates are released into the soil and devoured by populations of microorganisms. The bacteria, fungi, protozoa, algae, mites, nematodes, worms, ants, grubs, insects, beetles, and voles down there eat one another, replicate, metabolize waste, solubilize minerals, and make them bioavailable to the plants above. There is nonstop reciprocity that is undetectable to the human eye with more interactions happening under a stalk of corn than in all of New York City. As repeated ingestion of organisms proceeds unabated in the soil, carbohydrates and proteins become more complex and difficult to break down. The soil is not a commodity but a community. Writes Kristin Ohlson, "The carbon keeps cycling through the soil food web, and each time it's eaten and excreted it emerges in a more concentrated form. The process of decomposition is one in which the soil organisms keep creating longer and more complicated carbon chains. Thus, the carbon sugars in the simple syrup [exudates] that the plant created from sunlight ultimately is bound into a chain with maybe 10,000 other carbon atoms, which are themselves linked to hydrogen, oxygen, and other nutrients. As the carbon chains grow bigger, all that carbon keeps making the soil darker."

The average amount of carbon in farmland and grassland is 0.5 to 1 percent. How high can we build up carbon in the soil? We don't know. David Brandt's farm in Carroll, Ohio, started out at less than a half percent in 1978; today his farm is running at 8.5 percent carbon, greater than the 6 percent levels found in an adjoining woodlot. One caution expressed about soil carbon sequestration is that at some point it tops out and cannot exceed native levels of carbon. There is a limit to how much carbon soil can hold, but we do not know what that point is, and it is not limited by the soil's history. There is another reason soil may be a larger reservoir of carbon than is conventionally believed. Early soil science worked backwards in time to estimate how long it took to create an inch of soil—current textbooks say it takes a thousand years. The International Soil Reference and Information Centre state, "Soils are considered a finite resource as their formation and development requires hundreds to thousands of year (sic), as their loss and degradation is not recoverable within a human lifespan." Regenerative farmers are seeing an inch of new soil every four to ten years where there is sufficient moisture. While there are limits to how much carbon existing soil can hold, that does not preclude the creation of new layers of soil itself.

Feed the soil. Healthy soil feeds the plant and can provide what it needs without chemical inputs. This is visible in a mountain meadow, a grassland prairie, or a redwood forest: healthy, green, vibrant ecosystems with no fertilizers or external inputs. Farms can be the same. Tillage destroys soil communities and soil structure. No-till systems allow soil to evolve, build, and expand in breadth and complexity. When the soil is broken up, soil life is exposed to sun and weather; it dries out, dies, and emits carbon dioxide, which is one reason carbon levels in farmland have been reduced from an average of 3 percent to less than 1 percent today. The carbon in the soil represents organic matter that controls 90 percent of plant growth and health. The perils of tilling were well understood more than seventy years ago with the publication of the classic *Ploughman's Folly*, by Edward Faulkner. What overwhelmed traditional knowledge was the gains in yield afforded by plowing and chemical inputs. At a certain point, soils become addicted to fertilizers, as do farmers seeking ever higher yields. As with any addiction, withdrawal is painful because innate soil fertility is being lost and more inputs are required to maintain yields. Most farmers assume that you cannot achieve substantial yield without chemicals. That is not the case. Many regenerative farmers have achieved in-farm fertility, which require no external chemicals or inputs. Just like a forest.

Cover the soil. Cover crops protect the soil like a coat in winter or sunscreen in summer. A maxim for regenerative agriculture is that the sun should never see the soil. The idea is to keep as much green on top for as long as possible, because photosynthesis is how the sun's energy is metabolized. Bare ground cannot transform the sun's energy. Except for deserts, beaches, roadways, and rocky slopes, you rarely see bare ground in nature. When rain falls on covered ground during fallow periods, it does not dislodge the soil and cause erosion. In the summer, cover crops soften the fall of raindrops so that they fall gently to the soil, and protect it from drying and evaporation by the sun. However, they do far more than protect; they are the fertilizer factories for the soil and nourishment for animals. Cover crops sink their roots, enrich the soil, feed the microbiota with exudates, fix nitrogen from the air, and convert minerals, including potassium and phosphorus so that they become bioavailable. If cover crops are grazed by cows, sheep, horses, goats, or chickens, the surface of the soil is lightly disturbed and fertilized by urine and manure, which combine with and help break down the grasses, legumes, and clovers. More than 70 percent of the stored carbon in the soil is from dead roots. As the cover crops die off in the winter, they provide a layer on insulation to the soil and make more food available to the bacteria and organisms in the soil. In the fall or spring, remaining residue is crimped or munched down to enable annuals such as corn, soy, wheat, or other grains, as well as beans, to be drilled and sown. The mix and diversity of cover crops has exploded in recent years. Normal mixtures of vetch, clover, and rye have been joined by an agricultural fiesta of plant varieties that enhance soil life that look more like a vegetable garden: cowpeas, buckwheat, plantain, chicory, sunflower, fescue, daikon radish, Kodiak mustard, Ethiopian cabbage, Dundale peas, black-eyed peas, Languedoc vetch, hairy vetch, common vetch, chickling vetch, crimson clover, alfalfa, winter rye, fava beans, flax, black oats, chickpeas, purple top turnip, mung beans—you get the idea. The natural tallgrass prairies of yore towered so high they could hide a horse and contained more than two hundred species of plants. Together with animals and microbial life, cover crops and animal grazing can replace most of the 460 billion pounds of nitrogen fertilizer consumed annually, most of which ends up in streams, rivers, and ocean dead zones.

Hydrate the soil. Deserts start when available rainfall is not received and runs off. What matters on farmland is not how much water is delivered, but how much is retained. As soils lose their microbial life, they also lose structure; porosity dissipates and hardpan or more impermeable surfaces result. Healthy soil structure is illustrated by the difference between a muffin and sand: Place a muffin in a shallow dish of water and watch how it soaks up water. Place the same volume of sand in a dish, and no water will penetrate. The rate at which soils absorb rain or irrigation water is called the infiltration rate. A rich, crumbly soil structure is created by a sticky substance called glomalin, a soil protein created by fungi and humic acid, a dark, insoluble compound that remains in the soil for centuries or longer.



The American pioneer in regenerative agricultural science is George Washington Carver of Tuskegee University in Alabama. Like regenerative farmers today, he created a science of farming "forward," devising methods to improve soil health that employed crop rotation, nitrogen-fixing legumes, and the regeneration of soil health on lands depleted by monocultures. He drew upon Afro-indigenous agricultural knowledge and practices that go back more than two thousand years.

On conventionally farmed land, infiltration rates can be as low as a quarter inch per hour. More than that and water pools and runs off, causing erosion. Regenerative farmers experience ten to thirtyfold increases in water infiltration, from a half inch per hour to fifteen inches. Due to global warming, the atmosphere contains more water, and rainstorms are more severe. Houston had three five-hundred-year floods in each of three consecutive years (2015 to 2017). The odds of three in a row occurring were one in ten million, so this is the new normal, not a five-hundred-year flood. Worldwide flooding has increased fourfold since 1980. The capacity to capture as much water as possible is critical to prevent flooding and erosion. In Oklahoma, for every pound of wheat produced, three pounds of soil are lost to erosion. Improved water retention means greater plant growth, which creates greater photosynthetic capture of carbon. More carbon sequestration expands soil organic matter; more organic matter holds more water, and that means more food for people and animals.

Increased soil moisture also provides farmers with more of the resilience they need to deal with low volatile patterns of rainfall and droughts, which are also increasing in number because of warming. And there is another benefit. Approximately 80 percent of the earth's surface temperature is determined by the hydrosphere, the sum of all the water in and on the earth. Over the past two centuries, the earth has dried out. Deforestation, agriculture, overgrazing, and increased heat have desiccated lands, raising surface temperatures. Regenerative agriculture cools its environs. Surface temperatures can be 1-2°F lower, which helps plants grow.

Put creatures on or in the soil. Nature never farms without some types of animals. One of the hallmarks of modern farming was the separation of crops and animals. For thousands of years, they had been paired—every farm, pasture, or paddy had horses, cows, sheep, goats, geese, chickens, ducks, or (in Asia) fish. But that has changed. Crops and animals are now separated, in some cases by more than a thousand miles. What was lost are nutrient cycles. Fish can no longer survive in conventional rice paddies. Before the introduction of pesticides, they ate algae and insects and fertilized the crops. Farm animals grazed the land and were a source of manure and urea for the fields. In Western regenerative agriculture, the techniques of mob or rotational grazing engender rapid increases in soil carbon and fertility. Rotational grazing is effective because nothing stimulates exudate production better than grasses being chomped by a ruminant. It sends a powerful hormonal signal to the root to grow. If a farmer does not wish to be in the animal business, worms and vermiculture will also produce outstanding changes in soil fertility and carbon sequestration.

Soil health is plant health is human health. There can be no plant health without soil health. And there can be no human health without plant health. Minerals, trace minerals, microflora, and phytonutrients are essential for human wellbeing, and deficiencies can cause chronic illness. Even if you are eating a proper diet that theoretically provides the minerals your body needs, the plants you eat will not contain sufficient minerals if they are scarce in the soil. Plants depend on the soil microorganisms to solubilize minerals and make them bioavailable to the plant. And plants depend on stress in order to become more fully nutritious. Just as with humans, stress pushes a plant to change and adapt—to make its roots go deeper for water, minerals, or nutrients, or to change the chemical composition of its leaves to resist pests, for example. Conventional agriculture does the opposite. Everything a plant needs to grow in size and structure is provided close to the surface in the form of potash, superphosphate, and nitrogenous fertilizers. The soil is made sterile and the plant has less stress but are weak and vulnerable. Deficient plants are subject to insects, fungus, and rust, which can be swatted away using pesticides and fungicides. Competition is eliminated with herbicides, primarily glyphosate, a probable carcinogen. Conventionally farmed crops will grow faster, have shallower roots, and be less nutritious. Farmers get paid by weight, not by mineral or vitamin content. Crops tend to be overfed and undernourished, and so are our children. Chemical fertilizers are stimulating plants to grow bigger, faster, and fatter. And that is the same problem we have today, especially in the United States and other parts of the world that are adopting the American diet. Kids with obesity are actually starving, so they keep eating. We can hem and haw and beat around the food industry bush, but the facts are simple: chemically dependent plants do not create healthy food; ultraprocessed foods do not create healthy children; antibiotics and pharmaceutical drugs do not create healthy animals. Our fruits and vegetables have significantly less nutrition than they did fifty years ago. Foods are "enriched" because they are impoverished. In 1965, four percent of the U.S. population had a chronic disease; it is now two-thirds. Today, 46 percent of our children have a chronic disease. Regenerative farming improves plant nutrition without trying for a simple reason: it does not fight nature—it aligns with nature. Regenerative agriculture is at the heart of a regenerative society since it is the source of our food, nutrition, and well-being. A third of our total climate impact comes from our food system, as does a majority of human disease. The first principle of regeneration is to create more life. This is where we must start.